COMPUTER AIDED DESIGN POSSIBILITIES OF BOLTED CONNECTION

Imre Zsolt Miklos, Cristina Carmen Miklos, Carmen Inge Alic
University "Politehnica" Timisoara,
Faculty Engineering Hunedoara,
Revolutiei, 5, Hunedoara, 331128, Romania

ABSTRACT

This paper presents a modern and efficient way of designing bolted connection, using the specialized software packages CAD/CAE. We present a case study on assembling using bolted joints, with initial clamping and loaded with transversal forces. The 3D modeling of the studied threaded assembly (parts, screw, nut and washer) and the resistance calculations for a geometric case and data load were made using the Design Accelerator module, which is part of the Autodesk Inventor Professional package. This study was performed in a transparent and easy manageable manner, offering the possibility of viewing the results and modifying the input parameters at any time. In the final stage, we obtained the tension and deformation state of the threaded assembly components using the finite element method, respectively the Algor program.

KEYWORDS
Bolted connection, computer aided design, Inventor, stress analysis, Algor

1. INTRODUCTION

Threaded assemblies can be placed in the category of removable assemblies, and are made using standard machine parts (screws, nuts, washers). These assemblies are classified according to several criteria, such as their adjusting and the direction of the stress force. This paper presents some design and analysis possibilities for threaded assemblies loaded with transverse forces.

A characteristic of these assemblies is that the external forces have directions perpendicular to the screw axis. Such assemblies can be constructed in two ways: screw mounted without clearance (adjusted housing or matched) and screw mounted with clearance (or unmatched).

As these joints are commonly used in machine construction, their design implies detailed calculations, taking into account the conditions under which these machines operate.

Through continuous development of the CAD/CAE computer programs, the design of screw assemblies (the geometrical modeling and the calculation of resistance) can be made in a transparent and easy manageable manner, offering the possibility of viewing the results and modifying the input parameters at any time.

The assembly studied in this paper is a device for testing the bolted connections, with screws mounted with clearance and initial clamping loaded with transversal forces. The design and the finite element analysis of the assembly are performed using the computational packages CAD/CAE Inventor Professional, and Algor.

2. PARAMETRIC MODELING OF THE THREAD ASSEMBLY

The assembly provides the mounting of two pieces by two splice plates with three bolted connections, arranged according to fig. 1.

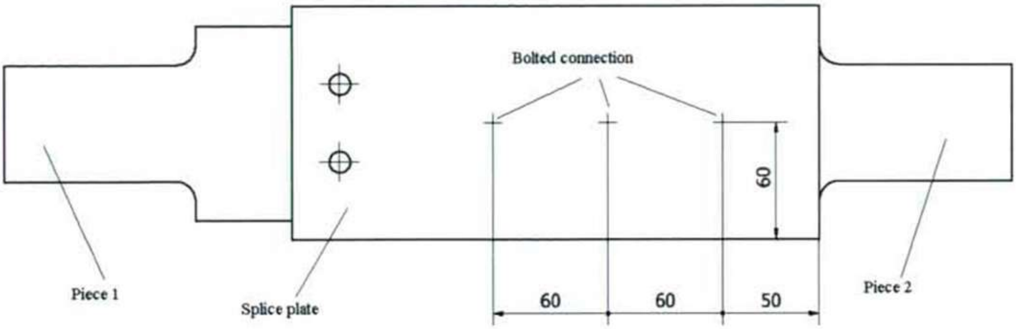

Fig.1. The bolted connection arrangement

The geometric (parametric) modeling of the three bolted connections was done using the Design Accelerator - Bolted Connection Generator module, from the Autodesk Inventor Professional program. The modeling involves inserting holes, screws, washers and nuts from the programs library of symbols, in agreement with the valid standards (fig. 2) for user-defined bolt diameter (M10), by specifying their insertion points (fig. 1) and limiting surfaces.

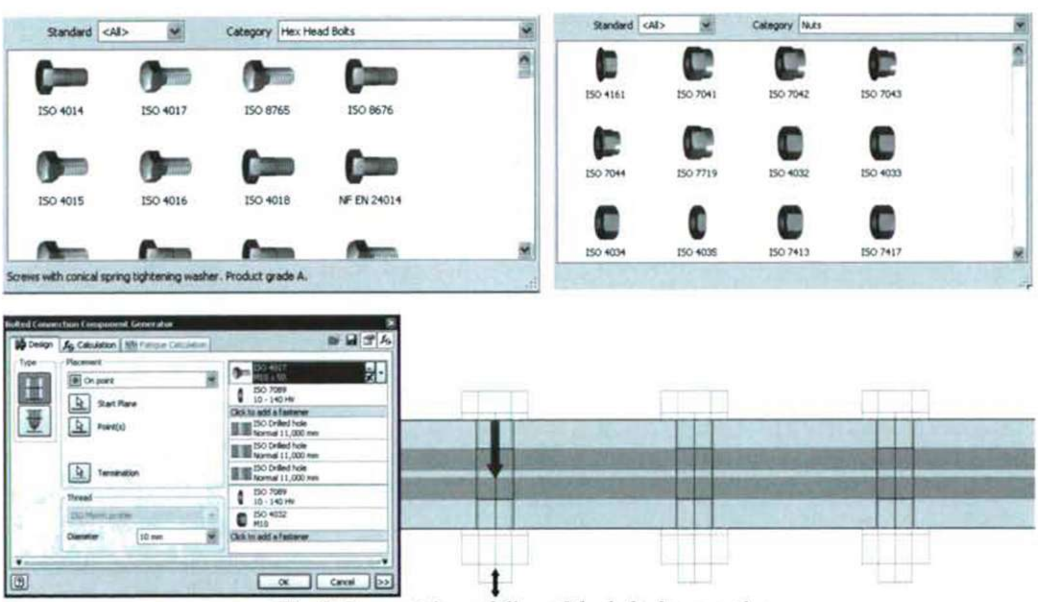

Fig. 2. Parametric modeling of the bolted connection

A section of the resulting parameterized 3D model of the assembly is shown in fig. 3.

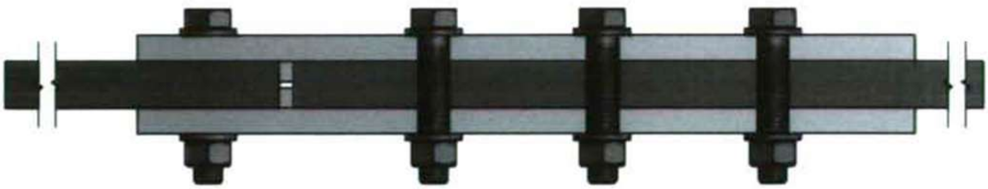

Fig. 3. Geometrical model of the assembly (2D section)

3. CALCULATION OF THE THREAD ASSEMBLY LOADED WITH TRANSVERSAL FORCES

In the case of assemblies made with screws mounted without clearance (Fig. 4), the transversal load on the screw is passed to the bolt of the screw, which will be loaded with shear and contact stresses. The relations used in the calculation are listed below:

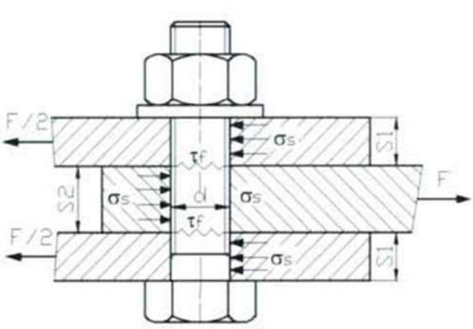

Fig. 4. Assembly with screws mounted clearance, loaded with transversal forces

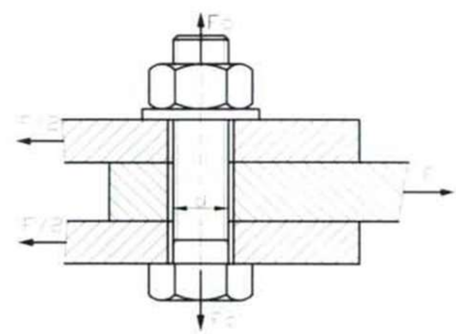

Fig. 5. Assembly with screws mounted with without clearance, loaded with transversal forces

Check to shear (determines the necessary diameter of the screw shaft):

$$\tau_f = \frac{4F}{i \cdot \pi \cdot d^2} \le \tau_{af} \qquad d_{nec} = \sqrt{\frac{4F}{i \cdot \pi \cdot \tau_{af}}}$$

Check to stress:

$$\sigma_s = \frac{F}{s \cdot d} \le \sigma_{as}$$

In the case of screw assemblies made with clearance (fig. 5), the transverse load F is carried by frictional forces, which occur between the parts closed with the initial clamping force F_0. This force must ensure a mutual fixing of the parts by friction and its total value is:

$$F_f = \mu \cdot i \cdot F_o \,,$$

While the fixing condition is given by:

$$F_f \geq \beta \cdot F,$$

where: β is a safety coefficient.
Substituting the value of the friction force, we obtained the clamping force Fo which ensures the contact between the pieces, respectively the screw tension:

$$F_o = \frac{\beta \cdot F}{\mu \cdot i} \qquad \sigma = \frac{4 \cdot 1{,}3 \cdot F_o}{\pi \cdot d_1^2} \leq \sigma_{at}$$

The additional torsion load of the assembly was also taken into account, through the coefficient 1.3.
These calculations of strength (checking or sizing) can be performed faster using the Bolted Connection Generator application from the Autodesk Inventor program. For the three bolted connections defined in paragraph 2 (fig. 2), we chose the option of checking the calculation, imputed the values of the forces that load the assembly, respectively of some coefficients specific to the threaded assemblies, and then chose the materials for the parts and screw. The geometrical dimensions of the thread were automatically uploaded. The interface with the Calculation tab is presented in fig. 6. As a result of the calculation, the program returns a message which validates or not the design.

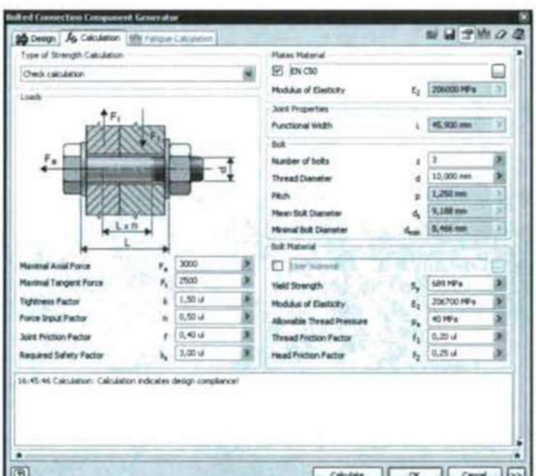

Fig. 6. Strength calculation of the bolted connection

4. ASSEMBLY ANALYSIS USING THE FINITE ELEMENT METHOD

The analysis of mechanical systems using the finite element method is a mathematical solution to engineering problems, which is based on dividing the studied bodies in discrete (finite) elements, in form of cubes and tetrahedrons. The analysis by finite element method allows us to determine the distribution of the stresses, specific deformations, movements, vibration analysis, for a loaded data and related constrains.
The analysis of mechanical systems by finite element method is carried out either through a rather complex matrix calculation, or using dedicated software packages such as: Algor,

Ansys, and Cosmos. In the following, the static analysis of a threaded assembly using the Algor program is presented.
As the Algor program allows modeling bolted connections as links between the assembled parts, we will use in this study a simplified 3D model, without the three bolted connections (only with holes for the screws), as shown in Fig. 7.
The modeling of bolted joints is achieved through defining the dimensions of the connection, respectively the surfaces between which the connections are made. The 3D model thus defined is presented in Fig. 8.

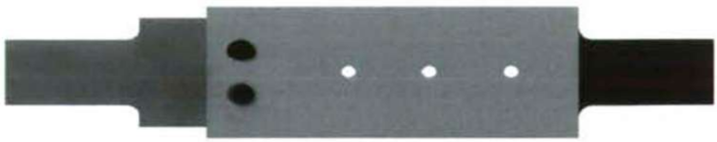

Fig. 7. Assembly simplified model

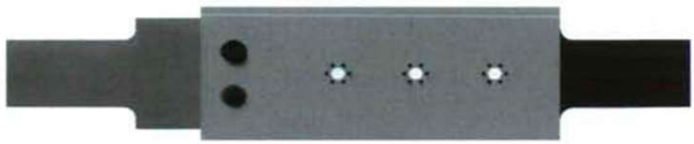

Fig. 8. Threaded assembly model

In the following, the specific stages of an analysis using the finite element method are presented, namely meshing the model, defining the type of elements and materials for each component of the assembly, that define the boundary condition and external loads. The final model for analysis is presented in fig. 9. Note that a contact surface was defined between the assembly parts, as there is friction between them (coefficient of friction $\mu = 0,1$).

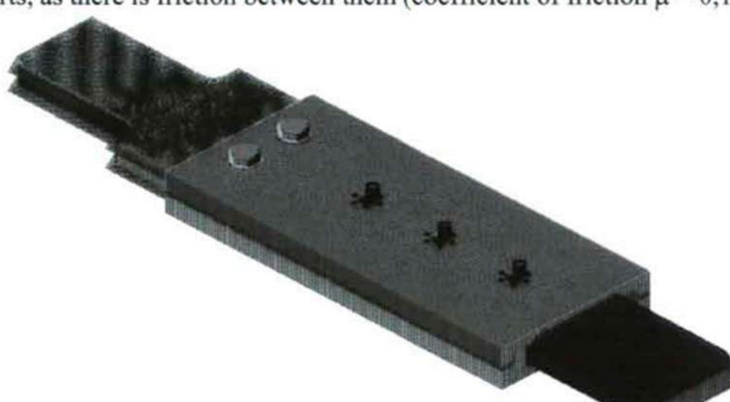

Fig. 9. The final model used for analysis

After the analysis is performed, we visualize and evaluate the results, such as von Misses stress distribution of the assembly (Fig. 10), the reaction forces and the axial stress of the bolted connection elements (Fig. 11, Fig.12).

Fig.10. Stress distribution in the elements assembly

Fig. 11. Reaction force from the bolted connection elements

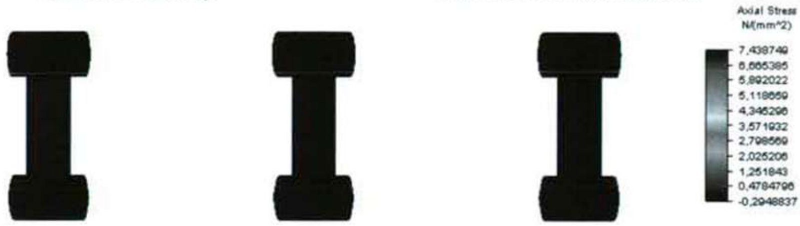

Fig. 12. The axial stresses in the bolted connection elements

5. CONCLUSIONS

The computer aided design of threaded assemblies, made with bolts fitted with clearance and initial clamping loaded with transversal forces, is an efficient, interactive, computationally cheap and fast way to design.
The results obtained by finite element analysis are comparable to those obtained in the laboratory using a real device.

REFERENCES

1. Cioată ,V., Miklos, I. Zs., Proiectare asistată de calculator cu Autodesk Inventor, Editura Mirton, Timişoara, 2009
2. Dolga, L., ş.a., Parametric and feature – based modeling with application in Catia and Inventor, Editura Politehnica, Timişoara, 2004
3. Gafiţeanu, M. ş.a., Organe de maşini. Vol. 2. Editura Tehnică, Bucureşti, 2002.
4. Miklos, I., Miklos, I. Zs., Mecanisme şi organe de maşini – lucrări de laborator, Editura Mirton, Timişoara, 2000
5. Miklos, I., Organe de maşini. Organe de asamblare, Editura Mirton, Timişoara, 2001
6. *** Algor User guide
7. www.algor.com
8. www.autodesk.com